

## **The basket shell, *Corbula gibba* Olivi, 1792 (Bivalve Mollusks) as a species resistant to environmental disturbances: A review**

Mirjana HRS-BRENKO

*Ruđer Bošković Institute, Center for Marine Research, Paliaga 5,  
52210 Rovinj, Croatia  
e-mail: brenko@cim.irb.hr*

---

*Structural changes in bottom communities in many coastal and offshore areas result from enhanced eutrophication and are characterized by the presence of species that are tolerant to a wide range of environmental disturbances. In soft bottom communities that are degraded or recovering from stress, *Corbula gibba* appears to be a highly abundant, ecologically important species and, therefore, an interesting subject for investigation. The literature compiled in this review reveals that, *Corbula* is a short-lived species with high fecundity, enormous production of small eggs, and a prolonged spawning season. The fertilization of spawned eggs in open waters is followed by pelagic development of larvae, accompanied by dispersal sometimes far from the mother population. High larvae settlement frequently appears as a "recruitment boom" in a new community after a catastrophe, making *Corbula* a short-term dominant species until the perished invertebrate species repopulate. As a dominant suspension feeder with rapid juvenile and adult growth, *Corbula* becomes an important element in the food chain as a transferor of organic matter from plankton to benthos. In a relatively stable soft-bottom community, the size of the *Corbula* population is mainly limited by the activity of competitors and predators. Dense *Corbula* populations may occur in a community with low species diversity in constantly and occasionally eutrophic areas. Generally, *Corbula* is considered an indicator of environmental instability caused by pollution, low oxygen content, or increased turbidity.*

---

**Key words:** Bivalvia, *Corbula gibba*

### **INTRODUCTION**

The basket shell, *Corbula gibba* (Olivi, 1792), is a small marine bivalve frequently sampled from soft-bottom communities in European seas. Due to its ecological importance in marine ecosystems, information about *Corbula* appears in many publications. This review is an attempt to amalgamate this information.

### **REVIEW**

#### **Taxonomic position**

GINANNI (1757) published the first short notice on the common basket shell under the name *Tellina gibba*, sampled about 14 nautical miles offshore from the Adige estuary in the northwest Adriatic Sea. The name *Corbula gibba* was

---

established later by OLIVI (1792). The species is located taxonomically as follows, according to the Check List of European Marine Mollusca (CLEMAM, MNHN, Paris).

Phylum: Mollusca Linné, 1758

Class: Bivalvia Linné, 1758  
 Subclass: Heterodonta Neumayr, 1884  
 Order: Myoida Stoliczka, 1870  
 Family: Corbulidae Lamarck, 1818  
 Species: *Corbula gibba* (Olivi, 1792: *Tellina*)  
 Synonyms: *Tellina gibba* Olivi, 1792  
*Mya inaequalis* Montagu, 1803  
*Corbula nucleus* Lamarck, 1818  
*Tellina olimpica* Costa O.G. 1829  
*Corbula ovata* Forbes 1838  
*Corbula nautica* Brusina 1870  
*Corbula curta* Locard, 1886

### Evolutionary history

The evolutionary history of the Corbulidae family began in the Tithonian stage of the Late Jurassic period (DÁVID, pers. comm.). Fossil *C. gibba* shells were found in Miocene sediments in marine Badenian marl facies in perturbed coastal areas of Croatia (KOCHANSKY, 1944; SREMAC, 1999), in molluscan clay and marine silty fine

grained sandstone in the Late Oligocene in Hungary (DÁVID, 1999a), and in Middle Miocene Korytnica clays of Poland (ZŁOTNIK, 2001).

### Geographic distribution

Today, this species is widely distributed in European seas (Table 1), from the Norwegian Sea southward to the Mediterranean and Black Seas (only near the Bosphorus) (YONGE, 1946; TEBBLE, 1966; NORDSIECK, 1969; SKARLATO & STAROBOGATOV, 1972; FREDJ, 1974; POPPE & GOTO, 1993). *Corbula* populations are distributed from low intertidal zones to considerable depths (Table 2). Individuals can penetrate down to 250 m (POPPE & GOTO, 1993; SALAS, 1996) and even deeper to 2200 m (NORDSIECK, 1969; FREDJ, 1974), but usually are found at depths to approximately 36 m.

In the late 1980s, *Corbula* was introduced to Australia where, in Port Phillip Bay, it became abundant in benthic communities (WILSON et al., 1998; TALMAN & KEOUGH, 2001). In some areas of this bay, *Corbula* reaches densities up to 2600 individuals m<sup>-2</sup> in sandy-muddy sediments at depths of 7-22 m (see Introduction in TALMAN & KEOUGH, 2001), similar to normal *Corbula* habitats in Europe.

Table 1. Selected literature on *Corbula gibba* distribution in European seas

Sea	References
Mediterranean	BONVICINI-PAGLIAI <i>et al.</i> (1985); BAKALEN & ROMANO (1988); THEODOROU (1994); SALAS (1996); ZENETOS (1996); BERNASCONI & STANLEY (1997); GIACOBBE & RINELLI (2002); ALBAYRAK <i>et al.</i> (2004)
Adriatic	VATOVA (1949); GAMULIN-BRIDA <i>et al.</i> (1968); SPECCHI & OREL (1968); ZAVODNIK (1971); HRS-BRENKO (1981, 1997, 2003); LEGAC & HRS-BRENKO (1982); STJEPČEVIĆ <i>et al.</i> (1982); SENEŠ (1988); OREL <i>et al.</i> (1989); CREMA <i>et al.</i> (1991); ALEFFI <i>et al.</i> (1992); VIO & DE MIN (1996); ZENETOS (1996); ADAMI <i>et al.</i> (1997); HRS-BRENKO <i>et al.</i> (1998); MOODLEY <i>et al.</i> (1998); ALEFFI & BETTOSO (2000); PEHARDA <i>et al.</i> (2002); SOLIS-WEISS <i>et al.</i> (2004)
Atlantic Coast	YONGE (1946); TEBBLE (1966); KITCHING <i>et al.</i> (1976); PEARSON & ELEFThERIOU (1981); JENSEN (1988, 1990); SALAS (1996); PRUVET (2000); RUEDA <i>et al.</i> (2001)
Kattegat and Baltic	ROSENBERG (1972, 1973, 1974, 1977); ARNTZ (1981); WEIGELT & RUMOHR (1986); BADEN <i>et al.</i> (1990); WEIGELT (1990); JOSEFSON & JENSEN (1992); ROSENBERG <i>et al.</i> (1992)

Table 2. Selected literature on population densities, sampling depth, and sediment type for *Corbula gibba* in various European localities

Locality	Density (ind/m <sup>2</sup> )	Depth (m)	Sediment type	Reference
<i>Northern Adriatic</i>				
Northern Adriatic	22400*	34-36	Loam	ŠIMUNOVIĆ <i>et al.</i> (1999)
Pula harbor	605**	8	...	HRS-BRENKO (1981)
Umag area (Istra)	470	16	...	HRS-BRENKO (1981)
ZI-012 (Istra)	1113**	23	Silty sand	HRS-BRENKO (present study)
Muggia Bay	2570	8-20	Mud	SOLIS-WEISS <i>et al.</i> (2004)
Northern Italian coast	4086***	12	Pelite	ALEFFI & BETTOSO (2000)
SJ-101 (Po River)	1217**	31	Clay	HRS-BRENKO (present study)
SJ-10 (Po River)	>1600	30	Silt	HRS-BRENKO (1981)
Ravena area	1001**	15	...	CREMA <i>et al.</i> (1991)
Ravena area	1800	18	Silty clay	MOODLEY <i>et al.</i> (1998)
<i>Other European Seas</i>				
Saltkällefjord (Sweden)	490	10	Sandy clay	ROSENBERG (1972)
Byfjord (Sweden)	4458	8	Silt	ROSENBERG (1977)
Oresund (Denmark)	1200 juv	18	Silty sand	MUUS (1973)
Limfjord (Denmark)	53000	3-8	Muddy clay	JENSEN (1990)
Limfjord (Denmark)	67000 juv	3-6	Clay	JENSEN (1988)
Dunkerque (France)	1090	...	Muddy sand	PRUVOT <i>et al.</i> (2000)
Off Cádiz (Spain)	166	26	Mud	SALAS (1996)
Elefsis Bay (Greece)	1396	20	...	THEODOROU (1994)

\*individuals hour<sup>-1</sup> by trawl\*\* mean individuals m<sup>-2</sup>\*\*\* individuals 50 l<sup>-1</sup>

### Population density

The population density of *C. gibba* (number of individuals per area) varies in space and time. Literature shows that dense *Corbula* populations are well represented in unstable environments such as constantly polluted bays and harbors and in coastal and offshore areas exposed to seasonal or occasional environmental disturbances. The density in the northern Adriatic is in good agreement with data in the literature (Fig. 1).

### Habitat

*Corbula*, an infaunal species with a sedentary mode of life, inhabits soft bottom sediments mixed with molluscan shell fragments. *Corbula*

uses byssal thread to attach to gravel, pebbles, or shell fragments (YONGE, 1946; TEBBLE, 1966; YONGE & THOMPSON, 1976; JENNSEN, 1988; POPPE & GOTO, 1993). Due to interstitial spaces, such sediments create convenient sheltered niches for settlement of *Corbula* larvae and protection from predators. LEGAC & LEGAC (1989) found live individuals inside unbroken amphoras filled with silt and rough sand, collected at depths of 17-31 m. In areas with coarser and clean sandy sediments, *Corbula* populations are rare or absent (HRS-BRENKO, 1981; ŠIMUNOVIĆ *et al.*, 1999; ALEFFI & BETTOSO, 2000).

Having a short siphon, *Corbula* burrows vertically and embeds itself into the upper 0-5 cm of the sediment (YONGE, 1946; ROSENBERG 1974; YONGE & THOMPSON, 1976; MOODLEY *et*



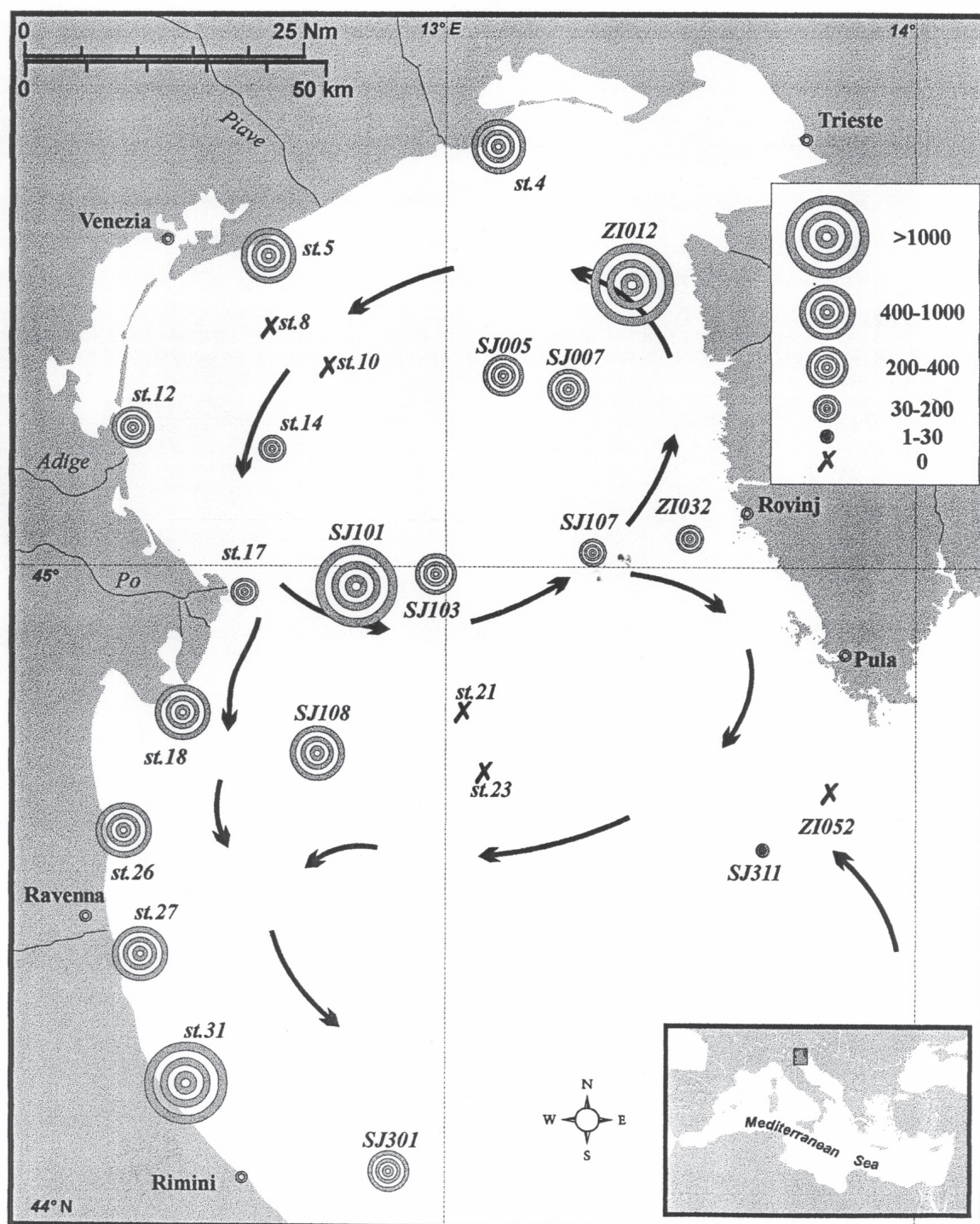


Fig. 1. Population density (individuals  $m^{-2}$ ) of *Corbula gibba* in the northern Adriatic Sea and seasonal surface sea currents (marked by arrows; ZORE-ARMANDA & VUČAK, 1984). *Corbula* data for stations (st.) 4, 5, 8, 10, 12, 14, 17, 18, 21, 23, 26, 27, and 31 were obtained by van VEEN grab (original data shown in individuals  $0.5 m^{-2}$  are converted to individuals  $m^{-2}$ ; ALEFFI & BETTOSO, 2000) and for stations (SJ) 005, 007, 101, 103, 107, 108, 301, 311 and (ZI) 012, 032, 052 by van VEEN grab (HRS-BRENKO, 2003, and unpublished data)

*al.*, 1998). The burrowing process is slow and described in detail by YONGE (1946). *Corbula* seldom emerge from the sediment unless disturbed (YONGE, 1946). PISAROVIĆ *et al.* (2000) recorded irregular *Corbula* movements in small finger bowls on the sediment surface prior to burrowing. The burrowing furrows are 3-5 mm in height and width. Individuals bury themselves one-third, two-thirds, or entirely. The authors observed that individuals may change position after embedding; they move and bury themselves at night or in darkness during the day.

### Spawning season

*Corbula* produces a large number of small eggs (60 µm diameter), fertilized in open waters (JØRGENSEN, 1946; THORSON, 1950). Information on the *Corbula* spawning season is scarce. GRAEFFE (1903) found many ripe individuals in the Trieste harbor in September while YONGE (1946) registered spawning in early October at the Isle of Cumbrae. BONVICINI-PAGLIAI & SERPAGLI (1988) discovered that June-September is the spawning season, based on complex micro growth patterns with marked growth breaks in thin sections of the shell.

BOON *et al.* (1998) reviewed the relationship between invertebrate reproduction and spring phytoplankton bloom. Polyunsaturated fatty acids, derived from phytoplankton in sedimentary and near-bottom particles, are essential compounds for reproduction and growth of many benthic species (BOON & DUINEVELD, 1996). Reproductive potential, growth, and abundance in the bivalve *Abra alba* increased in eutrophic environments, resulting in three spawning seasons per year instead of two as in oligotrophic conditions (DAUVIN & GENTIL, 1989). After an extraordinarily high phytoplankton bloom in the northern Adriatic Sea in 1989 (DEGOBBIS *et al.*, 2000), *Corbula* probably increased its fecundity and prolonged spawning and settlement seasons throughout almost all of the following year (HRS-BRENKO *et al.*, 1994; HRS-BRENKO, 2003), suggesting that *Corbula* may behave similarly to *Abra*.

### Larvae development and dispersion

*Corbula* has a long pelagic larval stage. The length of larvae development in bivalves is usually 2-4 weeks depending on the temperature and available food. In poor food conditions and at low temperatures, larval development is prolonged and often accompanied by high losses due to predation (THORSON, 1950). Until now, few studies focused on larvae development in *Corbula*. Larvae were found in plankton between March and June in the Rovinj harbor and the Limski Kanal in northern Adriatic (ODHNER, 1914). *Corbula* larvae were observed in Danish waters (MUUS, 1973) in October (JØRGENSEN, 1946; SCHRAM, 1962), July-August, October-November, and January-February, with a maximum in July (FOSSHAGEN, 1965). The finding of larvae in plankton in so many months clearly indicates a prolonged reproductive and larvae development season.

A long larvae development period promotes spatial distribution by sea currents, sometimes to considerable distances from parent populations (THORSON, 1950; GIANGRANDE *et al.*, 1994). In such a manner, planktonic larvae constantly expand existing populations in stable and damaged communities and colonize new zones, extending their distribution area.

In a large and relatively enclosed area such as the northern Adriatic Sea, larval distribution (except for diurnal migration between bottom and surface levels) depends on complex water circulation. In the spring, there is an imaginary east-west line between the Po River delta and Rovinj, north of which a cyclonic circulation system transports low salinity waters with silt from the vicinity of the Po River eastwards. This transversal current is accompanied by a southward current from the Po along the Italian coast (ZORE-ARMANDA & VUČAK, 1984; KRAJCAR, 2003). Both currents create ideal bottom conditions for the establishment of dense *Corbula* populations. The cyclonic water circulation encircles a zone north of the Po River-Rovinj line that is often eutrophic with stagnant water and soft bottoms highly populated by *Corbula*. This zone is assumed to be the main source of *Corbula* larvae dispersion throughout



the entire northern Adriatic, which is also true for other invertebrates with long pelagic larvae development periods. SPECCHI & OREL (1968) found that the renewal of *Corbula* populations in Muggia Bay depends on immigration of larvae from offshore zones.

Similarly, owing to the local current regime, *Corbula* populations are dense in the inner zones of closed bays, canals, fjords, and harbors characterized by unstable environmental conditions and polluted freshwater inflows. In such cases, the majority of *Corbula* individuals must come from local sources, especially when *Corbula* populations are negligible in neighboring zones (ROSENBERG, 1972, 1973; HRS-BRENKO, 1981; PRUVOT *et al.*, 2000).

### Recruitment

Recruitment is the process of larvae settlement and survival to 1 mm (JENSEN, 1988; DAME 1996). In species with long larvae development, such as *Corbula*, the length of the settlement season and its intensity significantly vary between years, depending on food supply, larval dispersion, predation, availability of appropriate bottoms, and environmental conditions (THORSON, 1950; GIANGRANDE *et al.*, 1994).

In high latitudes, MUUS (1973) recorded *Corbula* spat from mid-August to early January, ROSENBERG (1977) observed heavy and successful larvae settlement from September to November, and JENSEN (1988) reported on August and September. In the northern Adriatic, after the 1989 oxygen crisis, the settlement season of *Corbula* extended throughout the entire year of 1990 with a peak in summer at offshore and coastal stations (HRS-BRENKO *et al.*, 1994; HRS-BRENKO, 2003). ALEFFI *et al.* (1993) postulated that prolonged settlement seasons of *Corbula* results from high autumn temperatures and low competition for space after oxygen depletion.

Many studies have shown that *Corbula* settlements boom in favorable environmental conditions following the cessation of a particular stress agent. *Corbula* booms were observed after dredging canals (SPECCHI & OREL, 1968; BONVICINI PAGLIAI *et al.*, 1985), in the aftermath of oxygen crises and in oxygen deficient areas

(ROSENBERG, 1977; OREL *et al.*, 1989; BADEN *et al.*, 1990; ALEFFI *et al.*, 1992, 1993; HRS-BRENKO *et al.*, 1992b, 1994), and after cessation of industrial waste water discharges (ROSENBERG, 1972, 1973). In such circumstances, *Corbula* tends to aggregate thanks to the low species diversity in the bottom community (ROSENBERG, 1977).

The boom phenomenon characterizes *Corbula* as an opportunistic bivalve that, together with some invertebrates, immediately colonizes destroyed communities. In general, abundant *Corbula* juveniles indicate areas where an environmental disaster recently happened and damaged communities are in the early recovery phase. BONVICINI-PAGLIAI & SERPAGLI (1988) called *Corbula* an environmental stress species and a "time recorder" that indicates the beginning of macrofaunal succession after a catastrophe.

### Growth and life span

JØRGENSEN (1946) and MUUS (1973) recorded the length of *Corbula* in the prodissoconch stage (0.24-0.25 mm), at metamorphosis (0.25-0.33 mm), and after settlement (0.30-0.60 mm). Settled bivalves smaller than 2 mm are meiofauna, staying in this assemblage for about one month (THORSON, 1966).

The distribution of mean shell lengths of *Corbula* in Limfjord, Denmark (JENSEN, 1990) and length frequencies in the northern Adriatic (HRS-BRENKO, 2003) show that *Corbula* grow rapidly in spring and early summer. According to JENSEN (1990), *Corbula* growth ceases at temperatures below 13°C (October-May) while HRS-BRENKO (2003) observed the same phenomenon in winter. The increase in length during spring corresponds to the increased abundance of resuspended organic matter near the bottom and the bottom-living diatoms and bacteria that *Corbula* siphons from the bottom surface (YONGE, 1946; JENSEN, 1990). As an active suspension feeder, *Corbula* is an important transferor of organic matter to the benthos. This was evident during the early recovery period in 1990 when *Corbula* dominated the bottom community (HRS-BRENKO, 2003).

Table 3. Mean length at about one year and maximum length in second year of *Corbula gibba*

Locality	Mean length (mm)	Maximum length (mm)	Author
Isle of Man	8	12.0	JONES (1956) see: MUUS (1973)
Limfjord	6-7	10.8	JENSEN (1988, 1990)
Northern Adriatic	7-10	13.5	ALEFFI & BETTOSO (2000)
Northern Adriatic	6-8	14.7	HRS-BRENKO (2003)

*Corbula* reaches its maximum length at 16 mm (NORDSIECK, 1969). In the northern Adriatic, the longest *Corbula* specimen measured 14.7 mm (HRS-BRENKO, 2003). The scarce data on mean and maximum lengths of *Corbula* show similar growth patterns in various study areas during a two-year period (Table 3). *Corbula*, like other small benthic species, has a short life span of about two years with natural mortality beginning at 10 mm in the second year (ROSENBERG, 1977; JENSEN, 1990; ALEFFI *et al.*, 1993; HRS-BRENKO, 2003).

#### Survival: abiotic stress agents

*Corbula*, an inhabitant of unstable environments, tolerates anthropogenic and natural disturbances. In bays, fjords, and harbors with excessive organic matter (domestic and industrial wastes, oil, etc.), *Corbula* can develop dense populations because of the low species diversity in the community (GRAEFFE, 1903; ROSENBERG, 1972, 1973, 1977; HRS-BRENKO, 1981; BAKALEM & ROMANO, 1988; JENSEN, 1990; THEODOROU, 1994; ADAMI *et al.*, 1997; BORJA *et al.*, 2000; PRUVOT *et al.*, 2000; SOLIS-WEISS *et al.*, 2004). For this reason, *Corbula* is a bioindicator of pollution of sea bottom communities (FAO/UNEP, 1986) and belongs to the ecological group of r-selected species (GRAY, 1979; GIANGRANDE *et al.*, 1994).

In addition to its pollution tolerance, *Corbula* is an oxygen resistant species (ROSENBERG, 1977; DIAZ & ROSENBERG, 1995). It survives well for certain periods in low oxygen conditions but may diminish in prolonged hypoxia (BADEN *et al.*, 1990). This high oxygen resistance was confirmed in laboratory experiments in which adult *Corbula* survived several days in the

anaerobic conditions of starfish stomachs (CHRISTENSEN, 1970).

In a comprehensive review on the effects of hypoxia on benthic fauna, only *Corbula* survived mass mortality events (DIAZ & ROSENBERG, 1995). This was true in a sea loch, Lough Ine; (KITCHING *et al.*, 1976) and in the innermost part of a fjord in the Shetland Isles (PEARSON & ELEFThERIOU, 1981). *Corbula* survived together with a few other species in Kiel Bay (ARNTZ, 1981; WEIGELT & RUMOHR, 1986; WEIGELT, 1990) and the Kattegat area (BADEN *et al.*, 1990; JOSEFSON & JENSEN, 1992; ROSENBERG *et al.*, 1992). *Corbula* dominated in hypoxic water layers that covered anoxic layers in the Byfjord Estuary (ROSENBERG, 1977) while only *Corbula* was recorded in polluted Elefsis Bay in the Mediterranean in summer during strong thermal stratification accompanied by anoxic conditions (THEODOROU, 1994). *Corbula* survived frequent oxygen disasters in a sensitive northern Adriatic ecosystem (ALEFFI *et al.*, 1992; HRS-BRENKO *et al.*, 1992a, 1992b, 1994). Numerous live *Corbula* individuals were found among bottom deposited bivalve shells in the Malo Jezero salt lake (southern Adriatic) that is unpolluted but occasionally stressed with sulfide (PEHARDA *et al.*, 2002).

*Corbula* is resistant to high turbidity thanks to its ctenidia that efficiently separate organic from inorganic particles in resuspended bottom material (KIØRBOE & MØHLENBERG, 1981). Further, the asymmetric construction of the *Corbula* shell provides for better outflow of large amounts of pseudofeces (YONGE, 1946; YONGE & THOMPSON, 1976). Such features enable *Corbula* to form dense populations and survive in soft bottoms in closed bays with high sedimentation and reduced hydrodynamism (SOLIS-WEISS *et al.*,

2004) as well as in silted transversal currents in the northern Adriatic (HRS-BRENKO, 2003).

Most bivalve species protect themselves from temporary environmental stress by tightly closing their valves. *Corbula* does this well thanks to its special valve construction that allows hermetic shell closure (YONGE, 1946; YONGE & THOMPSON, 1976; BONVICINI-PAGLIAI & SERPAGLI, 1988). Shells formed in such a way keep the valves fast even after death. Many *Corbula* individuals sampled in the Adriatic with closed shells were either empty or filled with mud. This finding calls for careful inspection of whether *Corbula* individuals were alive at the time of sampling.

In addition to closing shells, bivalves have a protective mechanism that switches them to anaerobic metabolism by increasing the lactate concentration in the tissues (PISAROVIĆ *et al.*, 2000; ŽERJAV MEIXNER, 2000). Later, when normoxic conditions return, *Corbula* increases oxygen consumption for a short period of time to cover its "oxygen debt" during which accumulated anaerobic metabolic products are eliminated.

### Survival: biotic stress agents

Predation and competition are important biotic causes of losses of bivalve larvae, juveniles, and adults. During planktonic life, *Corbula* larvae can be preyed upon by ctenophores, jellyfish, copepods, invertebrate larvae, and pelagic fish. Mature larvae swimming near the bottom or crawling on the sediment are eliminated by suspension feeders. Surface and subsurface carnivores, deposit feeders, and omnivores prey on *Corbula* juveniles and adults. Finally, intra and interspecies competition for food and space significantly regulates species abundance in a bottom community (THORSON, 1950, 1966; MUUS, 1973; MILEIKOVSKY, 1974; CROWE *et al.*, 1987; JENSEN, 1988; KELLEY, 1988; MORTON, 1991; AMBROSE, 1993; ANDRÉ *et al.*, 1993; SEED, 1993; GIANGRANDE *et al.*, 1994; ÓLAFSON *et al.*, 1994; DAME, 1996; HRS-BRENKO, 1998; MOODLEY *et al.*, 1998; ZŁOTNIK, 2001). All these aspects create a complex interaction of biotic factors that

plays an important role in structuring benthic communities.

In spite of scarce evidence relating to meiofaunal and macrofaunal exterminators of *Corbula*, it is possible to speculate about its fate in the environment by considering the bivalve-predator and bivalve-competitor interactions mentioned above. Larger meiofaunal species may be active predators on recently settled *Corbula* larvae. If so, the reduced abundance of meiofaunal species (TRAVIZI, 2000) after the oxygen disaster in the Adriatic may have partly contributed to the simultaneous increase of the *Corbula* population during the ensuing six-month recovery period (HRS-BRENKO *et al.*, 1994).

At the macrofaunal level, in a stable bottom community, suspension feeders may accidentally inhale *Corbula* larvae during intensive filtration, decimating them prior to settlement. The ophiuroid *Amphiura filliformis*, a suspension feeder, may ingest larvae and newly settled juveniles of many invertebrates (CROWE *et al.*, 1987). The question is whether the period spent within the body of a suspension feeder is fatal for *Corbula* larvae. In the absence of numerous suspension feeders, *Corbula* may benefit from the low competition for space between survived invertebrates and among settling *Corbula* larvae. As with the bivalve suspension feeder, *Cerastoderma edule* (ANDRÉ *et al.*, 1993), *Corbula* may eliminate its own settling larvae and thus limit settlement intensity in areas where adults are abundant (JENSEN, 1988, 1990). It seems that such an adult-juvenile interaction occurred after the 1989 oxygen crisis in the northern Adriatic where the dominant adult population of 800 m<sup>-2</sup> may have postponed the larvae settlement peak to the summer; meanwhile, at another station, the adult density of only 153 m<sup>-2</sup> allowed high recruitment already in February. In this case, of course, other suspension feeders were also limiting settlement factors.

Competition for food and space can limit the *Corbula* population. For example, the bottom-dwelling *C. gibba* competes for food and space with another suspension feeding species, the off-bottom amphipod *Amphelisca* sp. (MOODLEY



*et al.*, 1998). When present in dense populations, *Amphelisca* consume detritus before it reaches the *Corbula* at the bottom, limiting the *Corbula* population. After widely occupying its new environment in Australia, *Corbula* significantly affected the juvenile size and growth of the native scallop *Pecten fumatus*, as both species are suspension feeders (TALMAN & KEOUGH, 2001). Another example of food competition was observed during the heavy *Corbula* settlement in February 1990, which was followed by mortality up to 45% in the 2.5 mm length class in March. Shells of sampled individuals were closed, empty, tiny, transparent, but undamaged. Without doubt, they were not eaten by predators but apparently died due to food limitation in the new densely populated community. ÓLAFSON *et al.* (1994) proposed that food limitation is a more important cause of mortality in newly settled invertebrates than in adults. JENSEN (1988) attributed the high mortality of *Corbula* juveniles (up to 31% in the first month after settling) to epibenthic predation while JENSEN (1990) attributed adult mortality to weakness after spawning.

Carnivorous gastropods, mobile crustaceans, starfishes, fishes, and birds are among the destructive bivalve predators. Predator-prey studies have mostly focused on commercial bivalves from shallow coastal and estuarine areas (MORTON, 1991; SEED, 1993; ÓLAFSON *et al.*, 1994; DAME, 1996). Little data related to predators of *Corbula* have been published.

Starfishes are voracious *Corbula* predators and frequently contain *Corbula* individuals in their stomachs (CHERBONNIER, 1966; SPECCHI & OREL, 1968; CHRISTENSEN, 1970; MILEIKOVSKY, 1974; JENSEN, 1988; POPPE & GOTO, 1993). In laboratory experiments, *Astropecten irregularis* excreted live *Corbula* adults several days after they were swallowed, which was not the case with juveniles of 2-3 mm (CHRISTENSEN, 1970). *Asterias rubens* and *Ophiotrix texturata* are also possible predators of juvenile *Corbula* immediately after settlement (JENSEN, 1988).

Since the Paleozoic era, carnivorous gastropods from the Muricidae and Naticidae families, predominantly *Natica* sp. and

*Euspira* (*Polynices*) sp., have attacked infaunal suspension feeding mollusks including *Corbula* by drilling holes in their shells (JEFFREYS, 1865, in YONGE, 1946; KOCHANSKY, 1944; KELLEY, 1988; MORTON, 1991; DÁVID, 1999a, b; SREMAC, 1999; ZŁOTNIK, 2001). The drilling process is described in ZIEGELMEIER (1954), YONGE & THOMPSON (1976), and others (see ZŁOTNIK, 2001). Large naticids prefer to attack the right valve of *Corbula* in the central-ventral region, while small naticids drill more or less equally into both valves (ZŁOTNIK, 2001). DÁVID (1999b) found more boreholes in the right valve and rounded boreholes were more common than sickle perforations. Round boreholes were made by *Natica* sp. (YONGE & THOMPSON, 1976; DÁVID, 1999a; PISAROVIĆ *et al.*, 2000; ZŁOTNIK, 2001). Although *Corbula* dominates over other invertebrate species in fossils and recent bottom samples, only 8% (PISAROVIĆ *et al.*, 2000) to 17-20% (ZŁOTNIK, 2001) were attacked by boring gastropods. All sizes of *Corbula* were attacked, but completely perforated boreholes were relatively rare. On the shell of a 2.7 mm Adriatic *Corbula*, only one of three boreholes was completely perforated. Owing to variation in shell thickness and a dense inner calcareous shell layer, *Corbula* is better protected against gastropod acid secretion than other bivalve species (YONGE, 1946; BONVICINI-PAGLIAI & SERPAGLI 1988; KELLEY, 1988; DÁVID, 1999b; ZŁOTNIK, 2001).

The crustaceans *Carcinus means* and *Crangon crangon* may also prey on *Corbula* (JENSEN, 1988) by smashing or chipping their shells. Fish from the Sparidae family and flat fishes from the Heterosomata order (KOVAČIĆ, pers. comm.) may swallow whole *Corbula* individuals. Many of these predators disappear from bottom communities when the oxygen level begins to drop. In such cases, the fish species either die or escape to normoxic areas, increasing fish catches there (STEFANON & BOLDRIN, 1982; DYER *et al.*, 1983; ŠIMUNOVIĆ *et al.*, 1999). In the interim, until predator fish species repopulate the damaged bottom communities either by returning as adults or by new recruitment, opportunistic species such as *Corbula* may proliferate.

## CONCLUSIONS

*Corbula gibba* (Olivi, 1792) is a widespread European bivalve with an evolutionary history dating back to the Paleozoic era. Dense *Corbula* populations are established in soft bottom communities with low species diversity and in constantly or occasionally unbalanced environments. The populations are distributed from low intertidal zones to considerable depths, but optimally down to approximately 36 m. In deeper coarser and clean sandy sediments, *Corbula* populations are rare or absent.

As an infaunal sedentary species, *Corbula* inhabits soft sediments mixed with gravel and molluscan shell fragments that are necessary for byssal thread attachment. Having a short siphon, *Corbula* burrows vertically near the sediment surface and emerges when disturbed. *Corbula* displays a light/dark reaction and burrows in dark conditions.

The scarce literature indicates *Corbula* has a prolonged reproductive season during which it produces many small eggs that are fertilized in open water. The pelagic larvae development period extends throughout the year. *Corbula* take advantage of favorable sea currents and human activities to expand existing populations, increase populations in damaged communities, and colonize new areas. The potential of *Corbula* recruitment is evident in damaged, degraded, and newly occupied areas where "recruitment booms" may occur in summer and autumn. As such, *Corbula* functions as an indicator of the recovery of the bottom community.

As a suspension feeder, *Corbula* uses mainly decomposed and resuspended organic matter to increase its fecundity and juvenile and adult growth rates. Thus, *Corbula* is an important participant in the flow of energy to the benthos, particularly when it is dominant in the community.

*Corbula* tolerates a wide range of abiotic environmental disturbances. For this reason *Corbula* is a bioindicator of pollution, turbidity, and low oxygen content in benthic communities. Biotic factors, such as competition and predation, are the main factors that limit the expansion of *Corbula* populations in a stable community. In stressed environments, *Corbula* dominates until its most sensitive competitor and predator recovers its own population. Voracious macrofaunal predators are starfishes, demersal fishes, and crabs, while carnivorous gastropods attack *Corbula* only occasionally, thanks to its hard shell and dense inner calcareous shell layer that is resistant to the acidic secretions of gastropods.

## ACKNOWLEDGEMENTS

The author thanks Dr. Stjepan KEČKEŠ and Dr. Nastjenka SUPIC for critical reading of the manuscript and useful comments, anonymous referees for constructive suggestions on the text and language improvement, and Mr. Željko STIPIĆ for preparing Fig. 1. This research was supported by the MINISTRY OF SCIENCE, EDUCATION AND SPORT OF THE REPUBLIC OF CROATIA (Project No. 00981302).

## REFERENCES

- ADAMI, G., F. ALEFFI, P. BARBIERI, A. FAVRETTO, S. PREDONZANI & E. REISENHOFER. 1997. Bivalves and heavy metals in polluted sediments - a chemometric approach. *Water, Air Soil Pollut.*, 99:615-622.
- ALBAYRAK, S., H. BALKIS & N. BALKIS. 2004. Bivalvia (Mollusca) fauna of the Sea Marmara. *Acta Adriat.*, 45(1):9-26.
- ALEFFI, F. & N. BETTOSO. 2000. Distribution of *Corbula gibba* (Bivalvia, Corbulidae) in the northern Adriatic Sea. *Annales, Ser. Hist. Nat.*, 10:173-180.
- ALEFFI, F., G. BRIZZI, D. DEL PIERO, F. GORIUP, P. LANDRI, G. OREL & E. VIO. 1992. Macro and meiobenthic responses to oxygen depletion in the Gulf of Trieste (northern Adriatic Sea, Italy). Preliminary results. *Rapp. Comm. int. Mer Médit.*, 33:343.
- ALEFFI, F., G. BRIZZI, D. DEL PIERO, F. GORIUP, P. LANDRI, G. OREL & E. VIO. 1993. Prime osservazioni sull'accrescimento di *Corbula gibba* (Mollusca, Bivalvia) nel Golfo di Trieste (Nord Adriatico). (First observations on the growth of *Corbula gibba* (Mollusca,

- Bivalvia) in the Gulf of Trieste). *Biologia Marina, Suppl. Notiz. S.I.B.M.*, 1:277-280.
- AMBROSE, W.G. Jr. 1993. Effects of predation and disturbance by ophiuroids on soft-bottom community structure in Oslofjord: Results of a mesocosm study. *Mar. Ecol. Prog. Ser.*, 97:225-236.
- ANDRÉ, C., P.R. JONSSON & M. LINDEGARTH. 1993. Predation on settling bivalve larvae by benthic suspension feeders: The role of hydrodynamics and larval behaviour. *Mar. Ecol. Prog. Ser.*, 97:183-193.
- ARNTZ, W. 1981. Zonation and dynamics of macrobenthos biomass in an area stressed by oxygen deficiency. In: G.W. Barret & R. Rosenberg (Editors). *Stress Effects on Natural Ecosystems*. J. Wiley & Sons Ltd. pp. 215-225.
- BADEN, S.P., L.O. LOO, L. PIHL & R. ROSENBERG. 1990. Effects of eutrophication on benthic communities including fish - Swedish west coast. *Ambio*, 19:113-122.
- BAKALEM, A. & J.C. ROMANO. 1988. Les peuplements benthiques du port d'Alger: 1 - Les Mollusques. (Benthic populations of the Algeirs harbour 1 - The Molluscs). *Rapp. Comm. int. Mer Médit.*, 31(2):16.
- BERNASCONI, M.P. & D.J. STANLEY. 1997. Molluscan biofacies, their distributions and current erosion on the Nile Delta Shelf. *J. Coast. Res.*, 13:1201-1212.
- BOON, A.R. & G.C.A. DUINEVELD. 1996. Phytopigments and fatty acids as molecular markers of near-bottom particulate organic matter in the North Sea. *J. Sea Res.*, 35:279-291.
- BOON, A.R., G.C.A. DUINEVELD, E.M. BERGHUIS & J.A. VAN DER WEELE. 1998. Relationship between benthic activity and the annual phytopigment cycle in near-bottom water and sediments in the southern North Sea. *Estuar. Coast. Shelf Sci.*, 46:1-13.
- BONVICINI-PAGLIAI, A.M. & F. SERPAGLI. 1988. *Corbula gibba* (Olivi) as a time recorder of environmental stress. A first contribution. *Rapp. Comm. int. Mer Médit.*, 31(2):17.
- BONVICINI-PAGLIAI, A.M., A.M. COGNETTI-VARRIALE, R. CREMA, M. CURINI GALLETTI & R. VANDINI ZUNARELLI. 1985. Environmental impact of extensive dredging in a coastal marine area. *Mar. Pollut. Bull.*, 16:483-88.
- BORJA, A., J. FRANKO & V. PÉREZ. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environment. *Mar. Pollut. Bull.*, 40:1100-1114.
- CHERBONNIER, G. 1966. Mode singulier d'expulsion du bivalve *Corbula gibba* (Olivi), absorbé par l'astérie *Astropecten africanus* Koehler. (Special mode of the expulsion of the bivalve *Corbulla gibba* (Olivi), absorbed by sea star *Africanus africanus* Koehler). *Bull. Mus. His. Natl. Paris, Ser. 2*, 38:270-273.
- CHRISTENSEN, A.M. 1970. Feeding biology of the sea star *Astropecten irregularis* Pennant. *Ophelia*, 8:1-134.
- CREMA, R., A. CASTELLI & D. PREVEDELI. 1991. Long term eutrophication effects on macrofaunal communities in the northern Adriatic Sea. *Mar. Pollut. Bull.*, 22:503-608.
- CROWE, W.A., A.B. JOSEFSON & I. SVANE. 1987. Influence of adult density on recruitment into soft sediments: a short-term *in situ* sublittoral experiment. *Mar. Ecol. Prog. Ser.*, 41:61-69.
- DAME, R.F. 1996. Ecology of marine bivalves an ecosystem approach. *CRC Mar. Sci. Ser.*, 254 pp.
- DAUVIN, J.C. & F. GENTIL. 1989. Long-term changes in populations of subtidal bivalves (*Abra alba* and *A. prismatica*) from Bay of Morlaix (western English Channel). *Mar. Biol.*, 103:63-73.
- DÁVID, Á. 1999a. Predation by naticid gastropods on late-Oligocene (Egerian) molluscs collected from Wind Brickyard, Eger, Hungary. *Malacological Newsletter*, 17:11-19.
- DÁVID, Á. 1999b. Naticid predation on the shells of middle Miocene Corbulids. A comparison (Ipolydamsd, Börzsöny Mountains, Hungary). In: Paper and poster abstracts, Biology & Evolution of the Bivalvia, 14-17 September 1999, Malacological Soc. London, Cambridge. p. 4.
- DEGOBBIS, D., R. PRECALI, I. IVANČIĆ, N. SMODLAKA, D. FUKS & S. KVEDER. 2000.

- Long term changes in the northern Adriatic ecosystem related to anthropogenic eutrophication. *Int. J. Environ. Pollut.*, 13:495-533.
- DIAZ, R.J. & R. ROSENBERG. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanogr. Mar. Biol. Annu. Rev.*, 33:246-303.
- DYER, M.F., J.G. POPE, P.D. FRY, R.J. LAW & J.E. PORTMANN. 1983. Changes in fish and benthos catches off the Danish coast in September 1981. *J. Mar. Biol. Ass. U.K.*, 63:767-775.
- FAO/UNEP. 1986. Rapport of the FAO/UNEP Meeting on the Effects of Pollution on the Marine Ecosystem. *FAO Fish Rep.*, 352, Rome, 20 pp.
- FOSSHAGEN, A. 1965. Bunnevertebratlarver over et *Venus*-samfunn i Öresund. (Benthic invertebrate larvae over a *Venus* community in Öresund). Thesis, Univ. Bergen, 70 pp.
- FREDJ, G. 1974. Stockage et exploitation des données écologie. Considération géographiques sur le peuplement benthique de la Méditerranée. (Stock and the exploitation of ecological data. Geographic consideration of the benthic populations in the Mediterranean Sea). *Mém. Inst. Océanogr.*, Monaco, 7:1-88.
- GAMULIN-BRIDA, H., A. POŽAR & D. ZAVODNIK. 1968. Contributions aux recherches sur la bionomie benthique des fonds meubles de l'Adriatique du Nord (II). (Contribution to the study of the benthic biocoenoses in the northern Adriatic coastal zone). *Biološki Glasnik*, 21:157-201.
- GIACOBBE, S. & P. RINELLI. 2002. *Corbula gibba* (Mollusca: Bivalvia) death assemblages in Augusta harbour, Mediterranean Sea. *J. Mar. Biol. Ass. U.K.*, 82:265-268.
- GIANGRANDE, A., S. GERACI & G. BELMONTE. 1994. Life-cycle and life-history diversity in marine invertebrates and the implications in community dynamics. *Oceanogr. Mar. Biol. Annu. Rev.*, 32:305-333.
- GINANNI, G. 1757. Testacei marittimi, paludosi e terrestri del'Adriatico e del territorio di Ravenna. (Marsh, terrestrial and marine testacei in the Adriatic Sea and in Ravenna territory). *Venezia*, 2:31.
- GRAEFFE, E. 1903. Uebersichte der Seetiere des Golfes von Triest, VI. Mollusca (Review of marine animals in the Gulf of Trieste. VI. Mollusca). *Arb. Zool. Inst. Wien, Zool. Sta. Trieste*, 14:89-136.
- GRAY, J.S. 1979. Pollution induced changes in populations. *Philos. Trans. R. Soc. Lond., B*, 286:545-561.
- HRS-BRENKO, M. 1981. Population studies of *Corbula gibba* (Olivi), Bivalvia, Corbulidae, in the northern Adriatic Sea. *J. Molluscan Stud.*, 47:17-24.
- HRS-BRENKO, M. 1997. The marine bivalve molluscs in the Kornati National Park and the Dugi Otok Natural Park (Adriatic Sea). *Period. Biol.*, 99:381-395.
- HRS-BRENKO, M. 1998. Considerations on the 1990 and 1991 bivalve repopulations in the northern Adriatic Sea (Croatia). *Period. Biol.*, 100:59-62.
- HRS-BRENKO, M. 2003. The role of bivalve *Corbula gibba* (Olivi, 1792) (Corbulidae, Mollusca Bivalvia) in the recruitment of benthic communities in the northern Adriatic (in Croatian). *Pomorski Zbornik*, 41:195-207.
- HRS-BRENKO, M., A. JAKLIN, E. ZAHTILA & D. MEDAKOVIĆ. 1992a. Školjkaši i nestašice kisika u sjevernom Jadranu. (Bivalve species and oxygen lack in the northern Adriatic Sea). *Pomorski Zbornik*, 30:581-597.
- HRS-BRENKO, M., D. MEDAKOVIĆ, E. ZAHTILA & Ž. LABURA. 1992b. Recovery of benthos after anoxic stress. II. Bivalve mollusks. *Rapp. Comm. int. Mer Médit.*, 33:347.
- HRS-BRENKO, M., D. MEDAKOVIĆ, Ž. LABURA & E. ZAHTILA. 1994. Bivalve recovery after a mass mortality in the autumn of 1989 in the northern Adriatic Sea. *Period. Biol.*, 96:455-458.
- HRS-BRENKO, M., M. LEGAC & M. ARKO-PIJEVAC. 1998. Contributions to the marine fauna of Rijeka Bay (Adriatic Sea). 3 Bivalvia.. In: M. Arko-Pijevac, M. Kovačić and D. Crnković (Editors). *Natural History Researches of the Rijeka Region. Natural History Library 1*, Natural History Museum Rijeka, pp. 583-607.



- JENSEN, J.N. 1988. Recruitment, growth and mortality of juvenile *Corbula gibba* and *Abra alba* in the Limfjord, Denmark. Kieler Meeresforsch. Sonderh., 6:357-365.
- JENSEN, J.N. 1990. Increased abundance and growth of the suspension-feeding bivalve *Corbula gibba* in a shallow part of the eutrophic Limfjord, Denmark. Neth. J. Sea Res., 27:101-108.
- JONES, N.S. 1956. The fauna and biomass of a muddy sand and deposit off Port Erin, Isle of Mann. J. Anim. Ecol., 25:217-252.
- JØRGENSEN, C.B. 1946. Lamellibranchia. In: G. Thorson (Editor). Reproduction and Larval Development of Danish Marine Bottom Invertebrates. Meddr. Komnn. Danm. Fisk.-og Havunders., Plankton, 4:1-523.
- JOSEFSON, A.B. & J.N. JENSEN. 1992. Effects of hypoxia on soft-sediment macrobenthos in southern Kattegat. In: G. Colombo *et al.* (Editors). Marine Eutrophication and Population Dynamics. Olsen & Olsen, Fredensborg, pp. 21-28.
- KELLEY, P.H. 1988. Predation by Miocene gastropods of the Chesapeake group: Stereotyped and predictable. Palaios, 3:436-448.
- KIØRBOE, T. & F. MØHLENBERG. 1981. Particle selection in suspension-feeding bivalves. Mar. Ecol. Prog. Ser., 5:291-296.
- KITCHING, J.A., F.J. EBLING, J.C. GABLE, R. HOARE, A.A.Q.R. Mc LEOD & T.A. NORTON. 1976. The ecology of Lough Ine. XIX. Seasonal changes in the western trough. J. Anim. Ecol., 45:731-758.
- KOCHANSKY, V. 1944. Fauna marinskog miocena južnog pobočja Medvednice (Zagrebačke gore). (Miocene marine fauna of the southern part of Medvednice (Zagreb mountain)). Vjesnik hrvatskog državnog geološkog zavoda i Hrvatskog državnog geološkog muzeja, 2/3: 171-280.
- KRAJCAR, V. 2003. Statistical approach to wind induced currents in the northern Adriatic. Geofizika, 20:93-104.
- LEGAC, M. & M. HRS-BRENKO. 1982. A contribution to the knowledge of bivalve species distribution in the insular zones of the northern and part of the middle Adriatic Sea. Acta Adriat., 23:197-225.
- LEGAC, M. & I. LEGAC. 1989. Amphoras - an interesting biotope of various flora and fauna species. Period. Biol., 91:122-123.
- MILEIKOVSKY, S.A. 1974. On predation of pelagic larvae and early juveniles of marine bottom invertebrates by adult benthic invertebrates and their passing alive through their predators. Mar. Biol., 26:303-311.
- MOODLEY, L., C.H.R. HEIP & J.J. MIDDELBURG. 1998. Benthic activity in sediments of the northwestern Adriatic Sea: sediment oxygen consumption, macro-and meiofauna dynamics. J. Sea Res., 40:263-280.
- MORTON, B. 1991. Cockles and mussels - alive, alive O. Univ. Hong Kong. Suppl. Gazette, 38:1-20.
- MUUS, K. 1973. Settling, growth and mortality of young bivalves in the Øresund. Ophelia, 12:79-116.
- NORDSIECK, F. 1969. Die europäischen Meeresmuscheln (Bivalvia). (The European sea bivalves (Bivalvia)). G. Fisher Verlag Stuttgart, 256 pp.
- ODHNER, N.H. 1914. Beiträge zur Kenntniss der marinen Molluskenfauna von Rovigno in Istrien. (Contribution to the knowledge of marine mollusk fauna from Rovinj on the Istrian peninsula). Zool. Anzeiger, 44:156-170.
- ÓLAFSSON, E.B., C.H. PETERSON & W.G. AMBROSE Jr. 1994. Does recruitment limitation structure populations and communities of macro-invertebrates in marine soft sediments: The relative significance of pre- and post-settlement processes. Oceanogr. Mar. Biol. Annu. Rev., 32:65-109.
- OLIVI, G. 1792. Zoologia Adriatica ossia Catalogo Regionales degli Animali del Golfo e delle Lagune di Venezia. (Adriatic zoology i.e. the regional catalogues of the animals in the Gulf of Trieste). Bassano, 334 pp.
- OREL, G., E. VIO & F. ALEFFI. 1989. Biocenosi bentoniche e loro modificazioni in seguito a stress anossici. (The benthic biocoenosis and their modification after anoxic stress). In: L'eutrofizzazione nel Mare Adriatico. Atti del Convegno Nazionale, Ancona, pp. 59-63.

- PEARSON, T.H. & A. ELEFThERIOU. 1981. The benthic ecology of Sullom Voe. Proc. Royal Soc. Edinburg, 80B:241-269.
- PEHARDA, M., M. HRS-BRENKO, D. BOGNER, D. LUČIĆ, V. ONOFRI & A. BENOVIĆ. 2002. Spatial distribution of live and dead bivalves in saltwater lake Malo Jezero (Mljet National Park). Period. Biol., 104:115-122.
- PISAROVIĆ, A., V. ŽERJAV-MEXINER & S. BENC. 2000. A contribution to the knowledge of bivalve *Corbula gibba* (Olivi, 1792) behaviour, oxygen consumption and anaerobic metabolism. Period. Biol., 102:303-307.
- POPPE, G.T. & Y. GOTO. 1993. European seashells (Scaphopoda, Bivalvia, Cephalopoda). 2. Verlag C. Hemmen, Wiesbaden, 221 pp.
- PRUVOT, C., A. EMPIS & N. DHAINAUT-COURTOIS. 2000. Présence du mollusque bivalve *Corbula gibba* (Olivi, 1792) dans les sédiments meubles du port Est de Dunkerque (Mer du Nord). (New record of the mollusk *Corbula gibba* (Olivi, 1792) in the muddy sands of Dunkirk harbour (Nord Sea)). Bull. Soc. Zool. Fr., 125:75-82.
- ROSENBERG, R. 1972. Benthic faunal recovery in a Swedish fjord following the closure of a sulphite pulp mill. Oikos, 23:92-108.
- ROSENBERG, R. 1973. Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite pulp mill. Oikos, 24:244-258.
- ROSENBERG, R. 1974. Spatial dispersion of an estuarine benthic faunal community J. Exp. Mar. Biol. Ecol., 15: 69-80.
- ROSENBERG, R. 1977. Benthic macrofaunal dynamics, production, and dispersion in an oxygen-deficient estuary of west Sweden. J. Exp. Mar. Biol. Ecol., 26:107-133.
- ROSENBERG, R., L.O. LOO & P. MÖLLER. 1992. Hypoxia, salinity and temperature as structuring factors for marine benthic communities in a eutrophic area. Neth. J. Sea Res., 30:121-129.
- RUEDA, J.L., M. FERNANDEZ CASADO, C. SALAS & S. GOFAS. 2001. Seasonality in a taxocenosis of molluscs from soft bottoms in the Bay of Cadiz (southern Spain). J. Mar. Biol. Ass. U.K., 81:903-912.
- SABELLI, B., R. GIANNUZZI-SAVELLI & D. BEDULLI. 1990. Catalogo annotato dei molluschi marini del Mediterraneo (Notated catalogue of the Mediterranean marine mollusks). Vol.1. Libreria Naturalistica Bolognese (Editor). Bologna, 348 pp.
- SALAS, C. 1996. Marine bivalves from off the southern Iberian Peninsula collected by the Balgim and Fauna 1 expeditions. Haliotis, 25:33-100.
- SCHRAM, T.A. 1962. Undersökelse av Bunn invertebratplanktonet i Öresund 1959-60. (Investigation of benthic invertebrate plankton in Öresund). Thesis, University of Oslo. 96 pp.
- SEED, R. 1993. Invertebrate predators and their role in structuring coastal and estuarine populations of filter feeding bivalves. In: R. Dame (Editor). Bivalve Filter Feeders in Estuarine and Coastal Ecosystem Processes. Springer-Verlag, Heidelberg. pp. 149-195.
- SENEŠ, J. 1988. Quantitative analysis of north and south Adriatic shelf ecosystems. Geol. Sbor. Geol. Carpath., 39:675-712
- ŠIMUNOVIĆ, A., C. PICCINETTI & M. ZORE-ARMANDA. 1999. Kill of benthic organisms as a response to an anoxic state in the northern Adriatic (a critical review). Acta Adriat., 40:37-64.
- SKARLATO, O.A. & J.I. STAROBOGATOV. 1972. Klass dvustvorčatye molljuski-Bivalvia. (The class of two valval Molluscs – Bivalvia). In: Opredelitel' fauny Černogo i Azovskogo Morej. 3. Svobodnoživuščie Bespozvonočnye. Naukova Dumka, Kiev, 178-249.
- SOLIS-WEISS, V., F. ALEFFI, N. BETTOSO, P. ROSSIN, G. OREL & S. FONDA-UMANI, 2004. Effects of industrial and urban pollution on the benthic macrofauna in the Bay of Muggia (industrial port of Trieste, Italy). Sci. Total Environ., 328: 247-263.
- SPECCHI, M. & G. OREL. 1968. I popolamenti dei fondi e delle rive del Vallone di Muggia presso Trieste. (The populations of the bottoms and the coast of the Muggia Bay near Trieste). Boll. Soc. Adr. Sc., Trieste, 56(1):137-171.

- SREMEC, J. 1999. Opća paleontologija. (The general paleontology). Mimeo. University of Zagreb.
- STEFANON, A. & A. BOLDRIN. 1982. The oxygen crisis of the Adriatic Sea waters in late fall 1977 and its effects on benthic communities. In: J. Blanchard, J. Mair and I. Morrison (Editors). Proc. 6<sup>th</sup> Int. Sci. Symp. World Underwater Federation (CMAS), Natl. Environ. Res. Council, pp. 167-175.
- STJEPČEVIĆ, J., P. PARENZAN, S. MANDIĆ & R. DRAGOVIĆ. 1982. Survey of benthic Mollusca population of the inner part of Boka Kotorska Bay. *Studia Marina*, 11-12:3-27.
- TALMAN, S.G. & M.J. KEOUGH. 2001. Impact of an exotic clam, *Corbula gibba*, on the commercial scallop, *Pecten fumatus*, in Port Phillip Bay, south-east Australia: evidence of resource-restricted growth in a subtidal environment. *Mar. Ecol. Prog. Ser.*, 221:135-143.
- TEBBLE, N. 1966. British Bivalve Seashells. A Handbook for Identification. The British Museum (Natural History), London, 212 pp.
- THEODOROU, A.J. 1994. The ecological state of the Elefsis Bay prior to the operation of the Athens Sea outfall. *Water Sci. Technol.*, 30:161-171.
- THORSON, G. 1950. Reproductive and larval ecology of marine bottom invertebrates. *Biol. Rev.*, 25:1-45.
- THORSON, G. 1966. Some factors influencing the recruitment and establishment of marine benthic communities. *Neth. J. Sea Res.*, 3:267-293.
- TRAVIZI, A. 2000. Effect of anoxic stress on density and distribution of sediment meiofauna. *Period. Biol.*, 102:207-215.
- VATOVA, A. 1949. La fauna bentonica dell'Alto e Medio Adriatico. (Benthic fauna of the upper and medium Adriatic). *Nova Thalassia*, 1:1-110.
- VIO, E. & R. DE MIN. 1996. Contributo alla conoscenza dei Mollusci Marini del Golfo di Trieste. (Contribution to the knowledge of the marine Molluscs in the Gulf of Trieste). *Atti Mus. Civ. Stor. Nat. Trieste*, 47:173-233.
- YONGE, C.M. 1946. On the habits and adaptations of *Aloidis (Corbula) gibba*. *J. Mar. Biol. Assoc. U.K.*, 26:358-376.
- YONGE, C.M. & T.E. THOMPSON. 1976. Living marine mollusks. Collins, London, 288 pp.
- WEIGELT, M. 1990. Oxygen conditions in the deep water of Kiel Bay and the impact of inflowing salt-rich water from Kattegat. *Meeresforschung*, 33:1-22.
- WEIGELT, M. & H. RUMOHR. 1986. Effects of wide-range oxygen depletion on benthic fauna and demersal fish in Kiel Bay 1981-1983. *Meeresforschung*, 31:124-136.
- WILSON, R.S., S. HEISLERS & G.C.B. POORE. 1998. Changes in benthic communities of Port Phillip Bay, Australia, between 1969 and 1995. *Mar. Freshwater Res.*, 49:847-881.
- ZAVODNIK, D. 1971. Contribution to the dynamics of benthic communities in the region of Rovinj (northern Adriatic). *Thalassia Jug.*, 7:447-514.
- ZENETOS, A. 1996. Fauna Graeciae VII. The Marine Bivalvia (Mollusca) of Greece. *Natl. Center Mar. Res., Hellenic Zool. Soc.*, 319 pp.
- ŽERJAV MEIXNER, V. 2000. Potrošnja kisika i ponašanje školjkaša *Corbula gibba* (Olivi, 1792) u eksperimentalnim uvjetima. (Oxygen consumption and the behaviour of shellfish *Corbula gibba* (Olivi, 1792) in the experimental conditions). Thesis, University of Zagreb, 98 pp.
- ZIEGELMEIER, E. 1954. Beobachtungen über den Nahrungserwerb bei der Naticide *Lunatia nitida* Donovan (Gastropoda Prosobranchia). (Observation of the feeding of Naticide *Lunatia nitida* Donovan (Gastropoda, Prosobranchia)). *Helgoländer Wiss. Meeresunters.*, 5:1-33.
- ZŁOTNIK, M. 2001. Size-related changes in predatory behaviour of naticid gastropods from the Middle Miocene Korytnica Clays, Poland. *Acta Palaeont. Polonica*, 46:87-97.
- ZORE-ARMANDA M. & Z. VUČAK. 1984. Some properties of the residual circulation in the northern Adriatic. *Acta Adriat.*, 25:101-117.

Received: 28 January 2005

Accepted: 11 January 2006

## **Školjkaš korbula, *Corbula gibba* (Olivi, 1792) (Bivalve Mollusks), otporna vrsta na poremećaje u okolišu. Pregledan rad**

Mirjana HRS-BRENKO

*Institut Ruđer Bošković Centar za istraživanje mora, Paliaga 5,  
52210 Rovinj Hrvatska  
e-mail: brenko@cim.irb.hr*

### **SAŽETAK**

Školjkaš korbula, *Corbula gibba* (Olivi, 1792), je rasprostranjena vrsta u evropskim morima i često je obilna u nestabilnim i eutrofiziranim sredinama. Zapažena kao ekološki važna vrsta u obnovi pridnenih zajednica u sjevernom Jadranu, nakon učestalih ugibanja vrsta makrobentosa uzrokovanih nestašicama kisika, korbula se smatrala zanimljivom vrstom za istraživanja populacijskih karakteristika. Pregled do sada objavljenih radova o korbuli ukazuje da je to mala kratko živuća vrsta visokog reproduksijskog potencijala s obilnom proizvodnjom malih spolnih stanica tijekom produžene sezone mriješćenja. Oplodnja jajnih stanica i razvoj ličinki u planktonskoj zajednici omogućuje njeno širenje u nova područja, kao i u područja osiromašena vrstama nakon katastrofalnih ugibanja. Slobodni prostori, nastali nakon ugibanja brojnih vrsta u pridnenoj zajednici, omogućuju korbuli intenzivno naseljavanje novcima, u prvoj fazi obnove makrobentosa. Tada kao dominirajuća «suspension feeding» vrsta korbula postaje važnim prenosnikom proizvedene organske tvari iz fitoplanktona u bentos. U kasnijem periodu obnove pridnenih zajednica znatno se smanjuje veličina populacije korbule. Čini se da tome pridonosi kratak životni vijek korbule kao i obnova predatorskih vrsta. Sažeto rečeno korbula se zbog svoje otpornosti prema učestalim promjenama sredine smatra indikatorom nestabilnosti, najčešće uzrokovanim sniženjem slanoće morske vode, te pojačanim turbiditetom i zagađivačima, u okolišu snižene bioraznolikosti.

**Ključne riječi:** Bivalvia, *Corbula gibba*

---